Auxiliary Feedwater Reliability Study

1 AFW SYSTEM FAULT TREE MODELS

The fault tree models for the eleven design classes shown in Figure 4 illustrate the logic used for generating the 72 plant-specific AFW unreliability models. Plant-specific models were generated since there are some differences in the AFW configurations within a design class. These differences are described in Section D-2 of Appendix D.

1.1 AFW Unreliability for an Operational Mission

This section documents the results of the reliability analyses performed using the AFW 1987–1995 experience. Estimates of AFW unreliability for the actual missions experienced were calculated. These unreliability estimates are based on the AFW missions that result from routine transients including a normal reactor trip in which main feedwater is commonly isolated, producing a low level in the steam generators and a demand for auxiliary feedwater. These demands for AFW operation can range from a few minutes (when main feedwater is immediately returned to service) to a few hours (when the plant operators rely on AFW and don't restore main feedwater). This information related to these events is referred to as belonging to an operational mission (i.e., AFW operational unreliability).

1.2 AFW System Modeling Assumptions for an Operational Mission

The fault tree models for the eleven design classes shown in Figure 4 provided the logic used for generating the 72 plant-specific AFW unreliability models. The eleven AFW design class models were developed to categorize the levels of steam generator, and pump train redundancy and diversity across the industry. Plant-specific models were developed from the eleven models to identify differences in the feed control/injection path redundancy within a design class. These differences are described later in Section 3.2.5. The unreliability of the AFW system was calculated for an operational mission using the plant-specific fault tree models. The models were constructed to reflect the failure modes identified in the unplanned demand data and the levels of redundancy and diversity of the AFW piping segments. In most cases, the models used the success criteria stated in the PRA/IPEs (refer to Table 1 for the success criteria). However, the success criterion for several plants was modified to eliminate the non-safety class pump trains modeled in some PRA/IPEs. Since LERs are not required to be submitted for these types of pump trains, estimates for these types of non-safety components were not calculated.

Estimates of AFW unreliability were calculated using the 1987–1995 experience. These data were statistically analyzed to develop failure probabilities (see Appendices A and E for the details on the statistical applications and methods). The following failure modes are based on the 1987–1995 experience:

- Failure to Start—Turbine-driven pump steam supply valves and associated piping (FTS-ST)
- Failure to Start—Pump, driver, valves and associated piping (FTS)
- Failure to Run—Pump, driver, valves and associated piping (FTR)
- Maintenance-out-of-service—Pump, driver, valves, and associated piping (MOOS)
- Failure to Operate—Feed control/injection header valves (AFW feed control/isolation, etc.) and associated piping faults (FTO-INJ).

Table 4 contains the failure mode probabilities and associated uncertainty intervals calculated from the 1987–1995 experience for the independent failures. Table 3 provides the estimates for the Alpha factors ($\alpha_{k/n}$) used in the CCF quantification. The following conditions were assumed for the purposes of quantifying the operational mission fault tree:

- A demand to provide auxiliary feedwater to a steam generator is received by the AFW system.
- The FTR contribution to the unreliability is estimated on a per mission demand.
- The condensate storage tank is assumed to meet all needs for auxiliary feedwater. Alternate suction sources are not modeled.

1.3 AFW System Model Assumptions

The following conditions were assumed:

- A demand for AFW flow to a steam generator is received by the AFW system.
- The FTR contribution to the unreliability assumes a mission time stated in the PRA/IPE. These times are presented in Table 1 of the system description.
- The AFW system success criterion is for transients that results in reactor trip and a loss of main feedwater and are based on those reported in the PRA/IPEs except where the success criterion uses a non-safety pump train. In these cases, the success criterion was modified to eliminate the non-safety pump train. The success criterion depicted in the logic models is presented in Table 1 of the system description.
- Alternate suction sources are not modeled.

The component failure modes were grouped according to the following breakdown:

Suction path segment (SUC)

FTO—Failure of the suction path valves and associated piping from the preferred water source (e.g., condensate storage tank) to deliver the flow to the pump trains necessary for AFW success.

Turbine steam supply (ST)

FTS—Failure to operate of the steam supply valves and associated piping upstream of the turbine steam stop valve.

Pump train segment (M or T or D)

FTS—AFW pump train failure to start, failure of the actuation circuit, and valve failures in the pump train suction and discharge piping.

FTR—Failure to run of the AFW pump train.

MOOS—Unavailability of the AFW pump train due to maintenance.

Feed control/injection header segment (INJ)

FTO—Failure of the steam generator injection paths/flow control valves and associated valves and piping to deliver the flow necessary for AFW success.

1.4 AFW Fault Tree Models

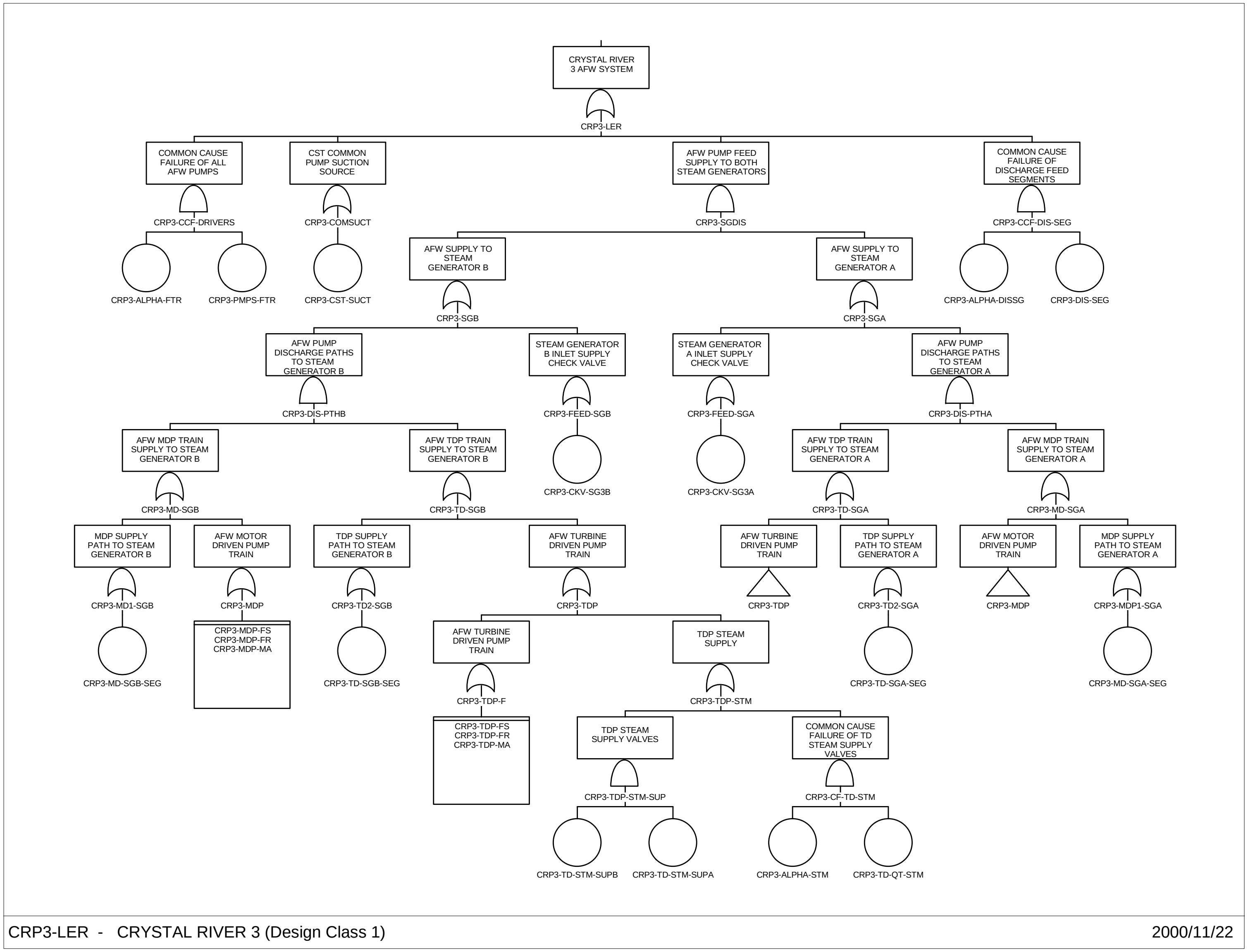


Figure 1. Design Class 1.

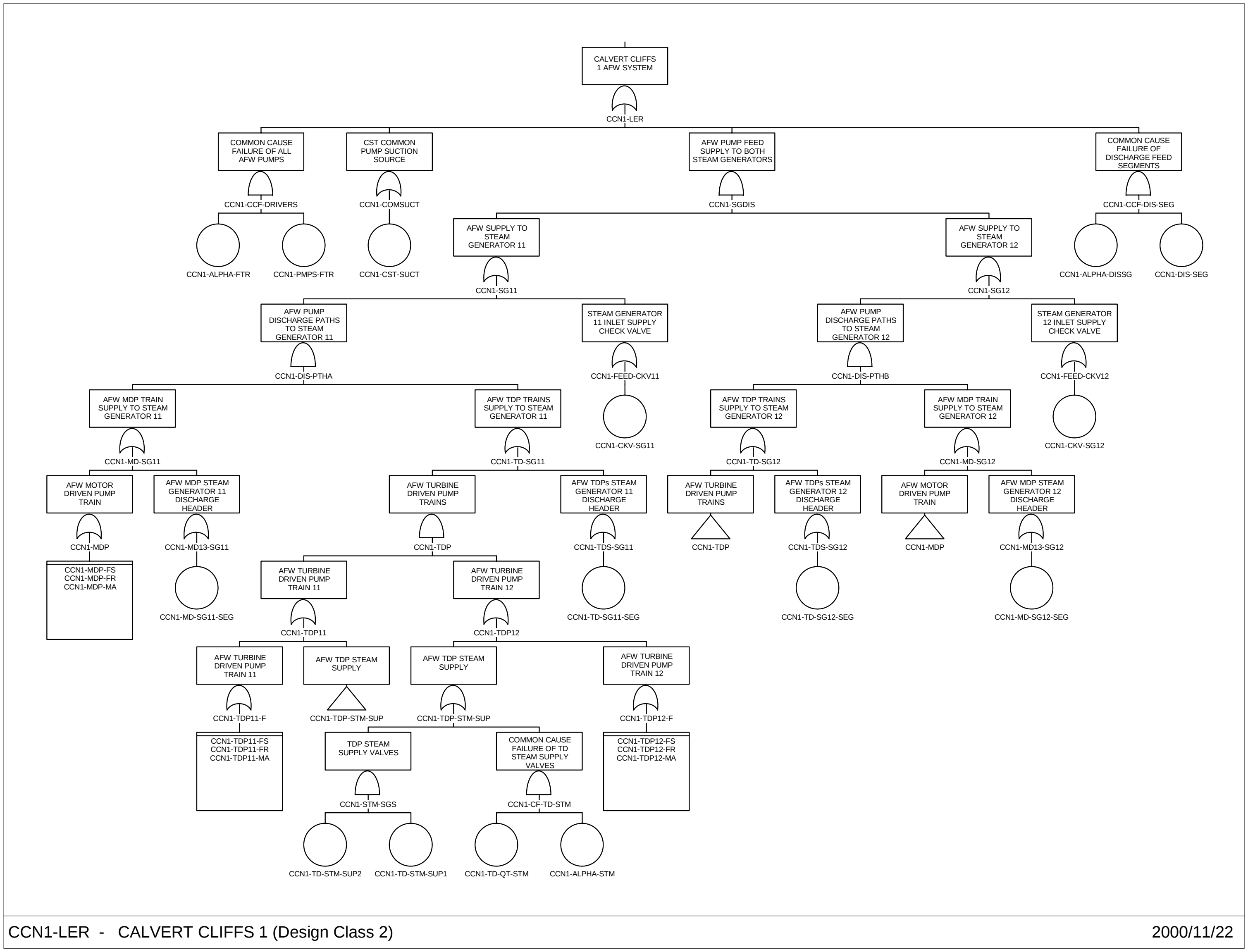


Figure 2. Design Class 2.

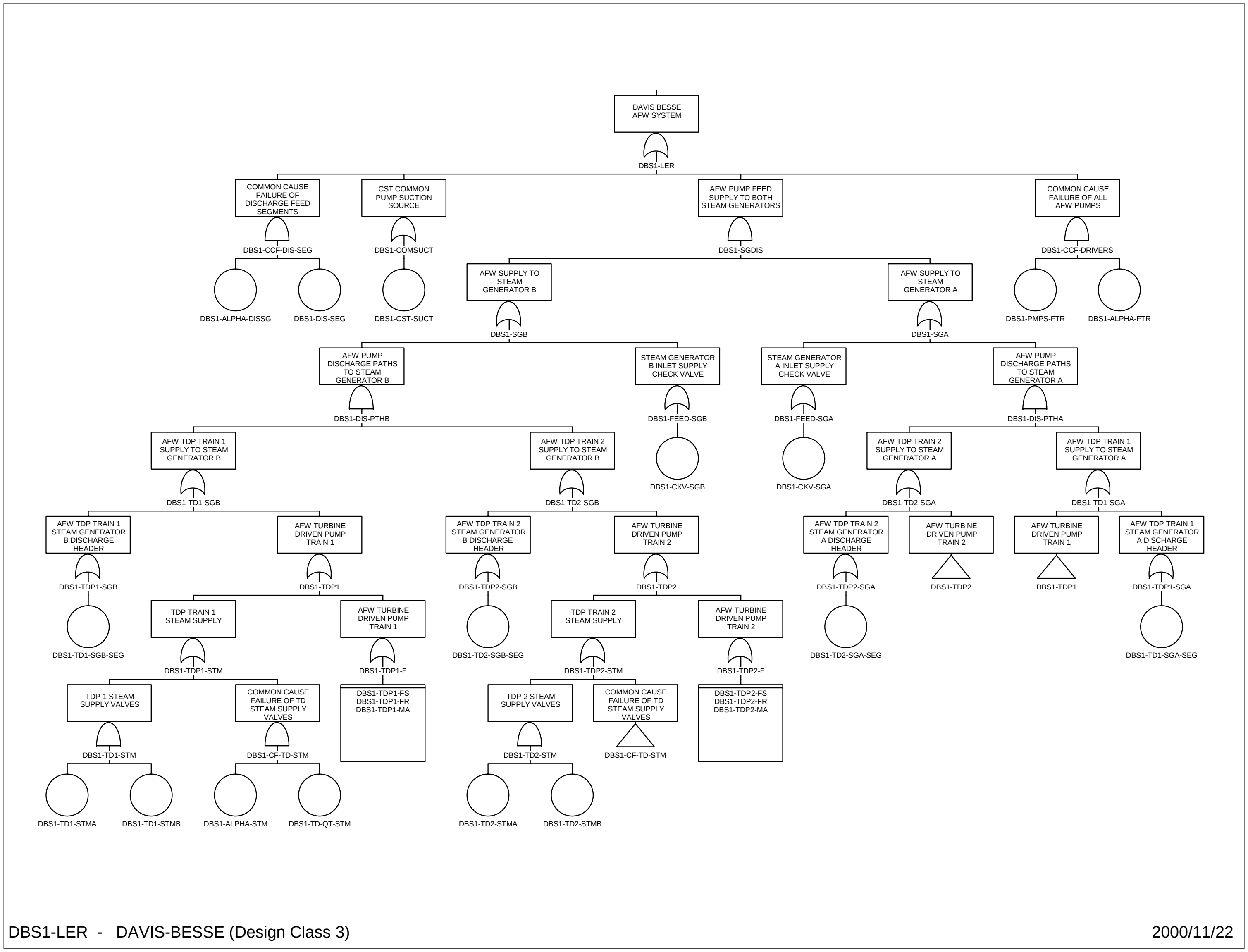


Figure 3. Design Class 3.

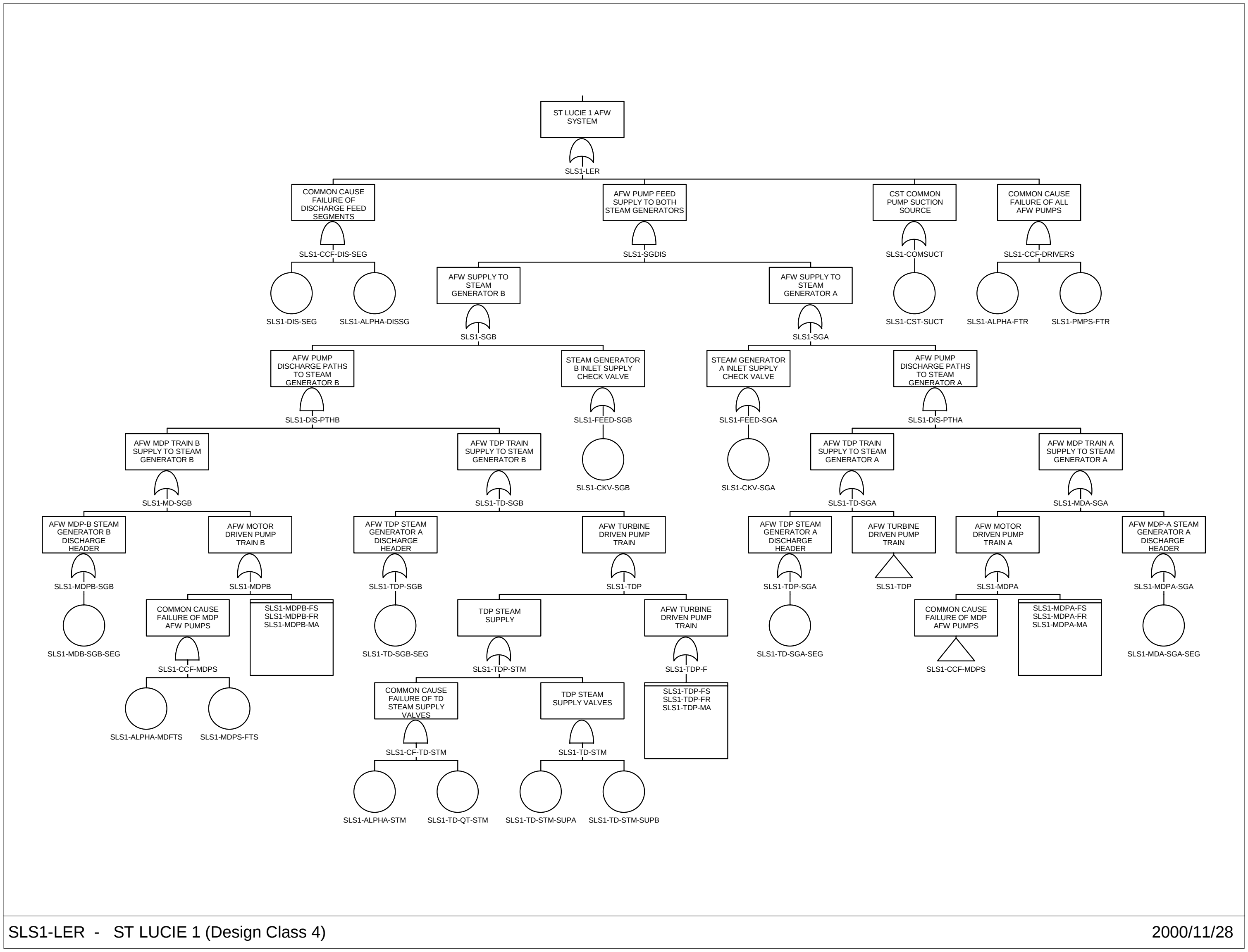


Figure 4. Design Class 4.

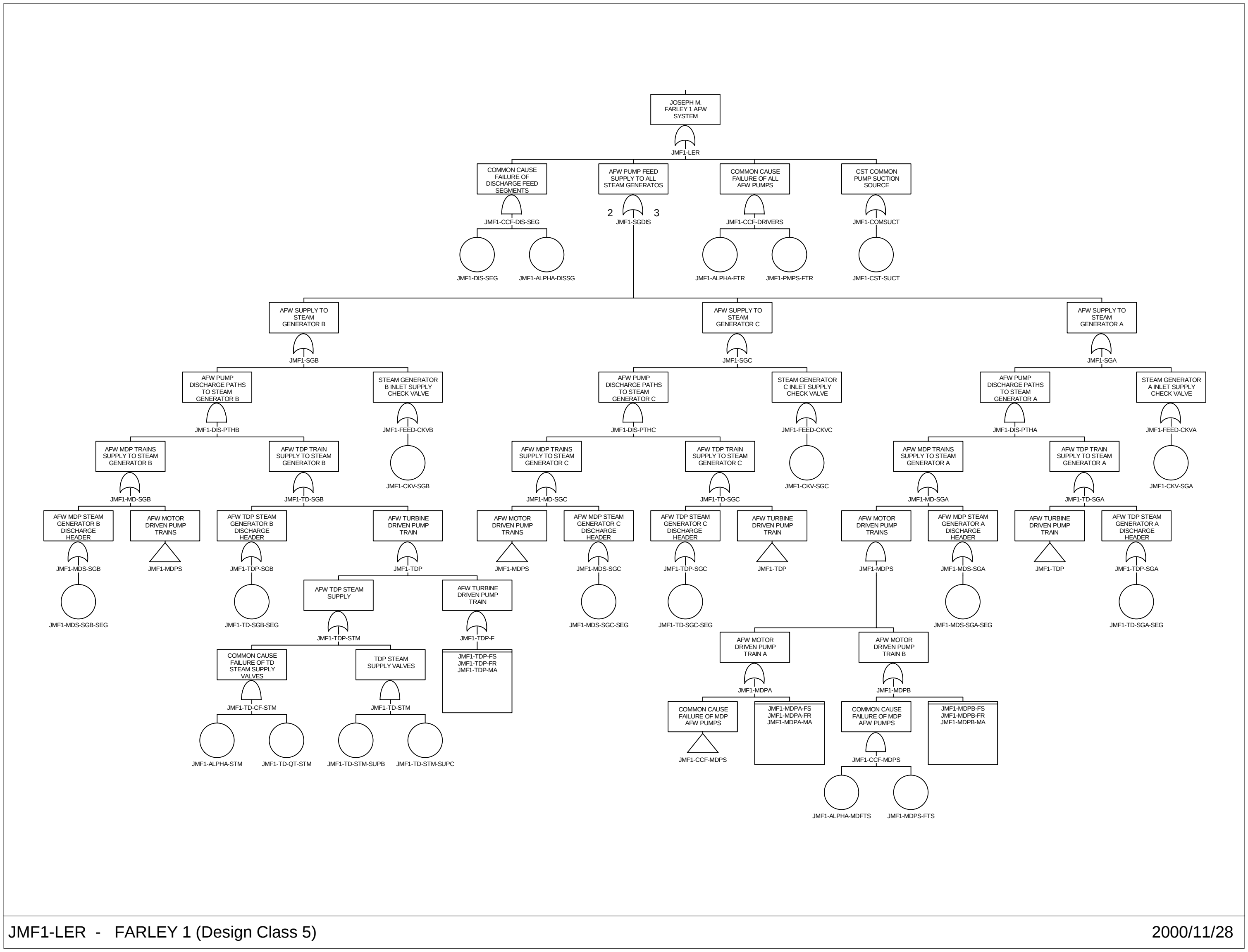
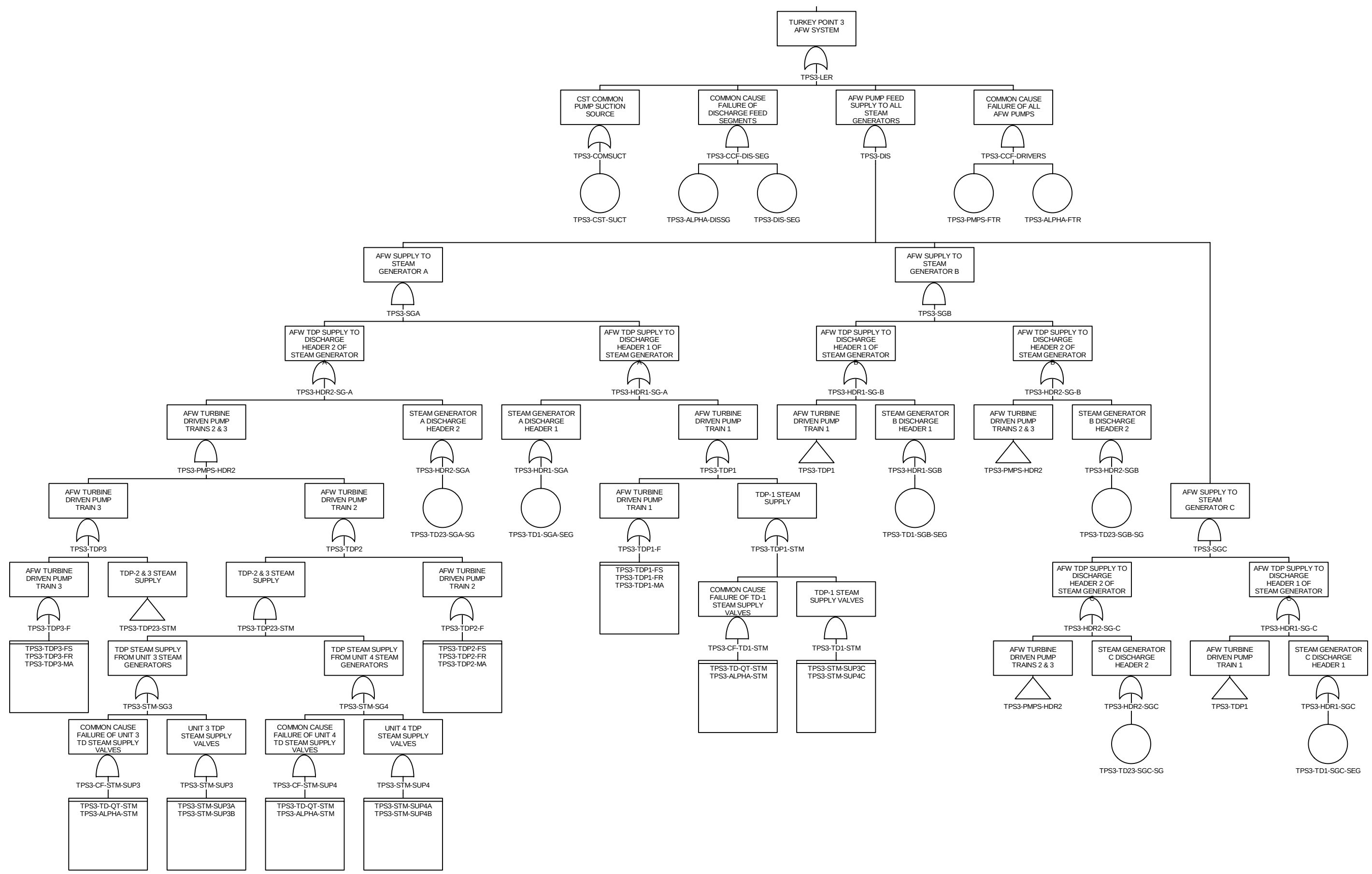
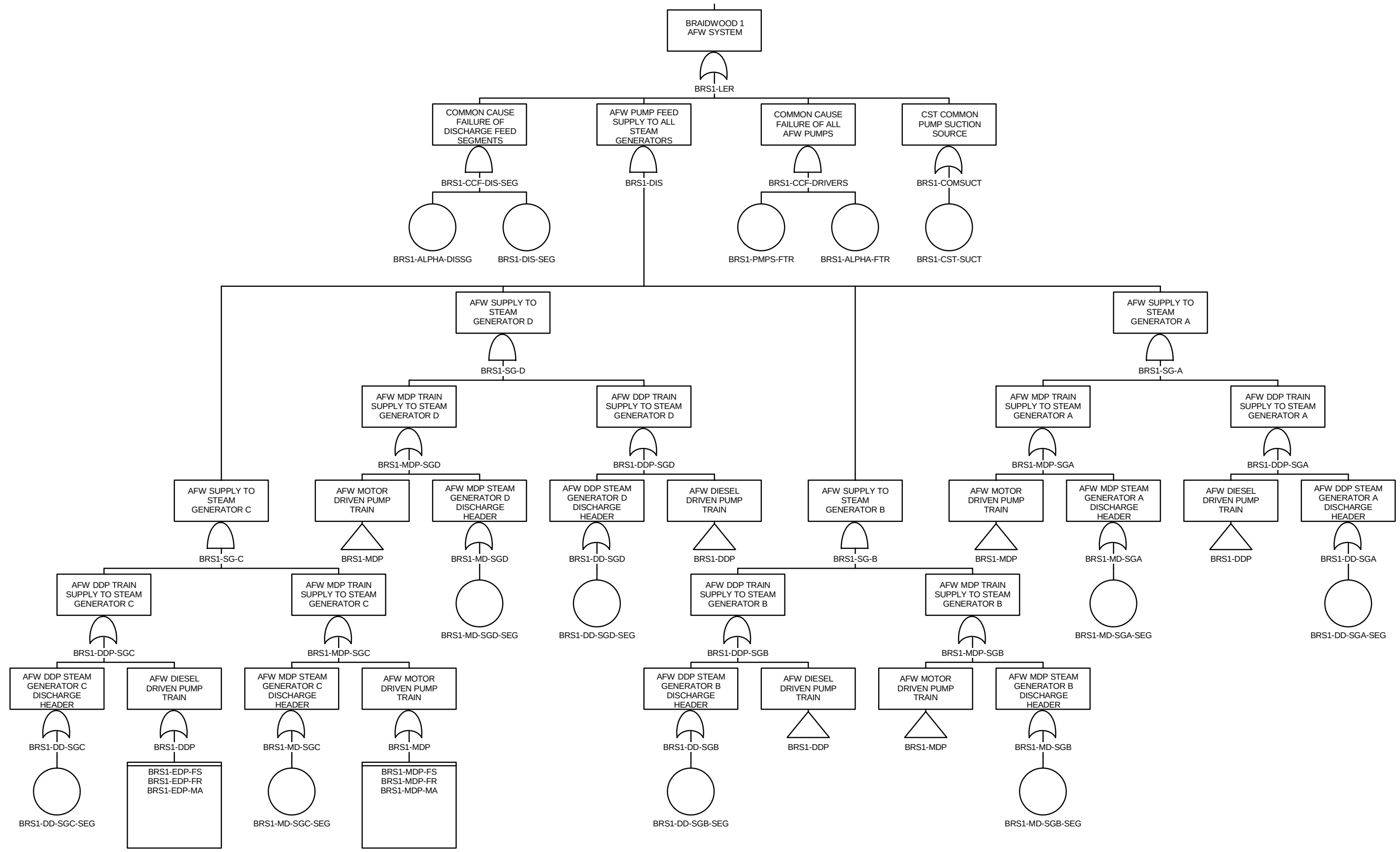


Figure 5. Design Class 5.



TPS3-LER - TURKEY POINT 3 (Design Class 6) 2000/11/22

Figure 6. Design Class 6.



BRS1-LER - BRAIDWOOD 1 (Design Class 7) 2000/11/22

Figure 7. Design Class 7.

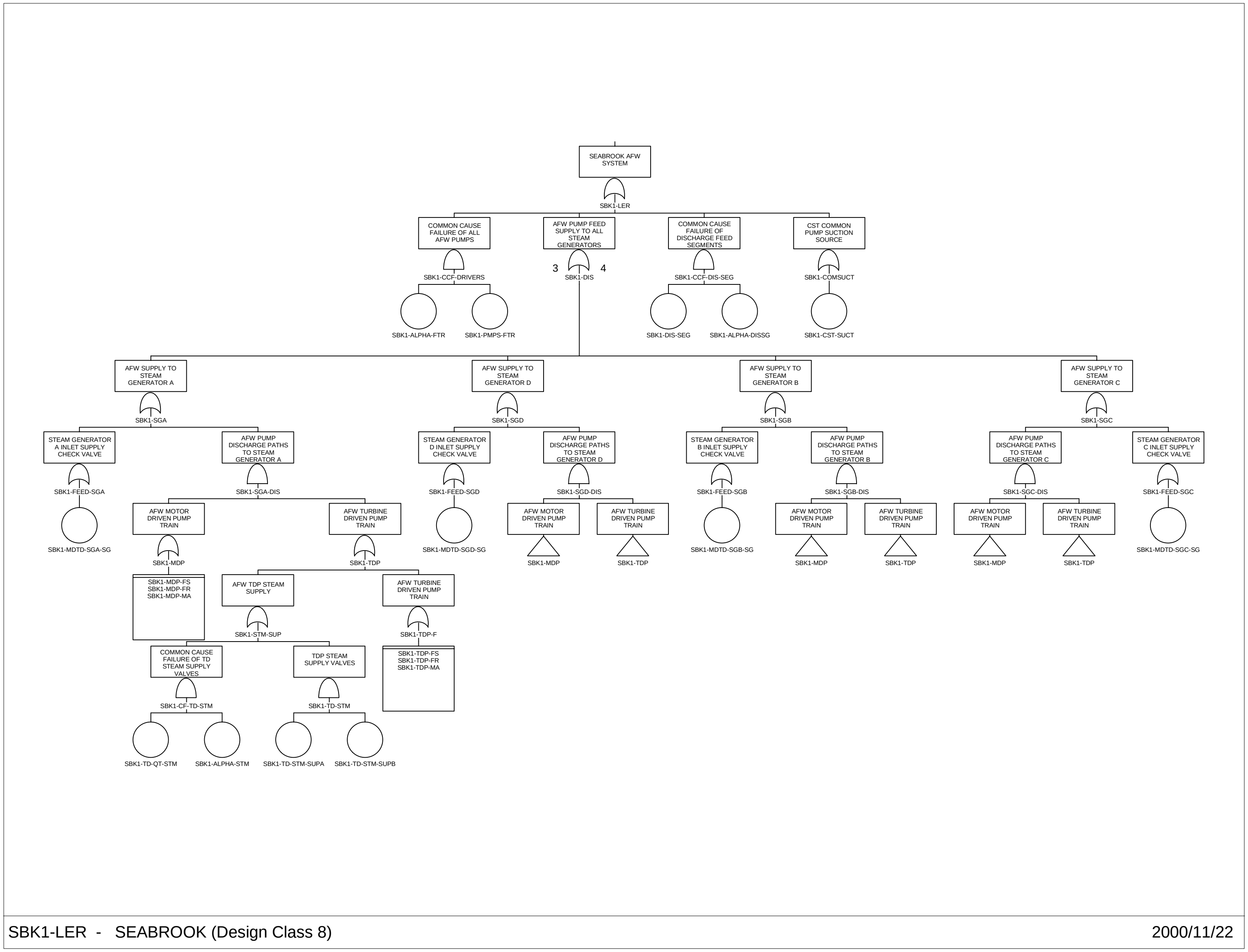


Figure 8. Design Class 8.

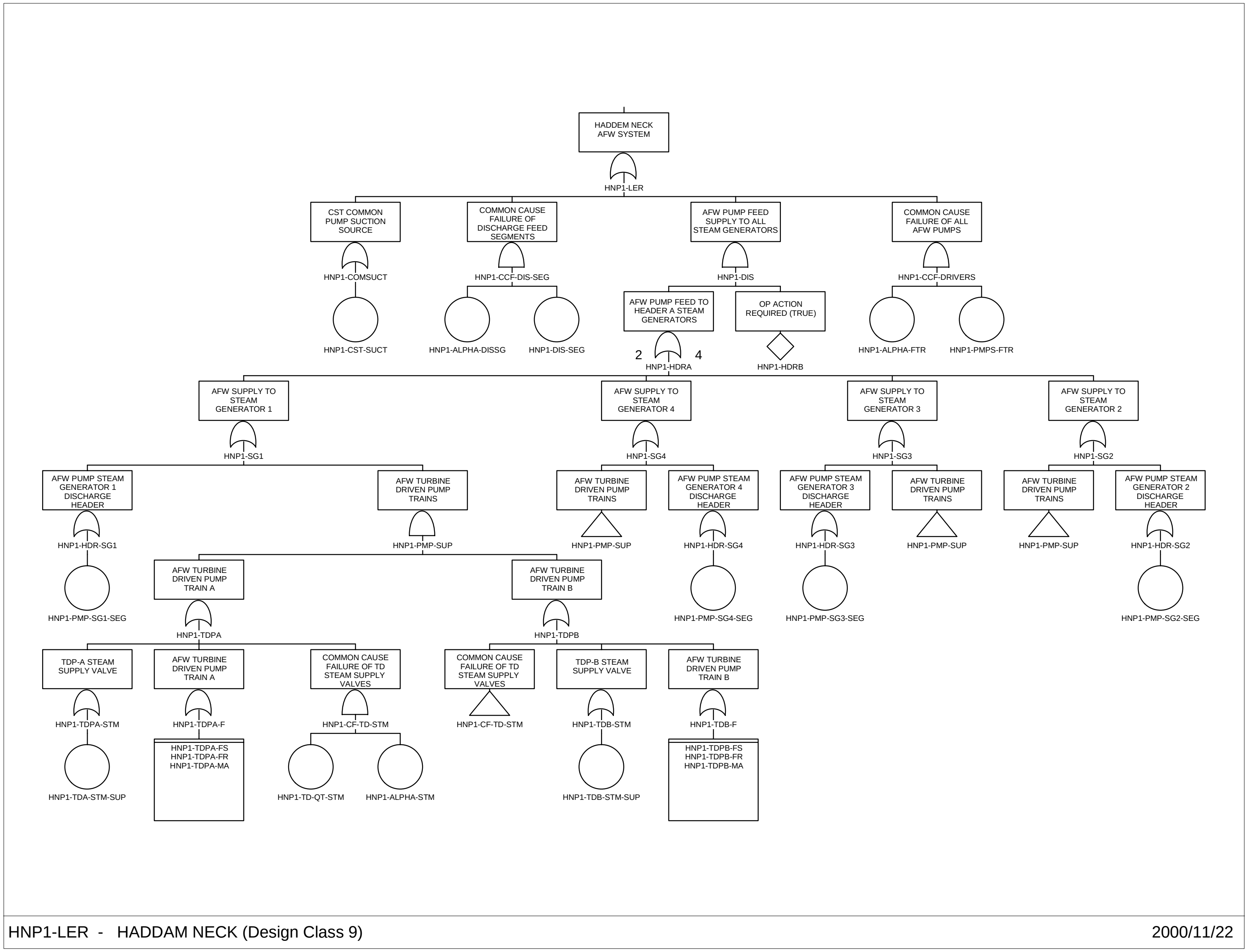


Figure 9. Design Class 9.

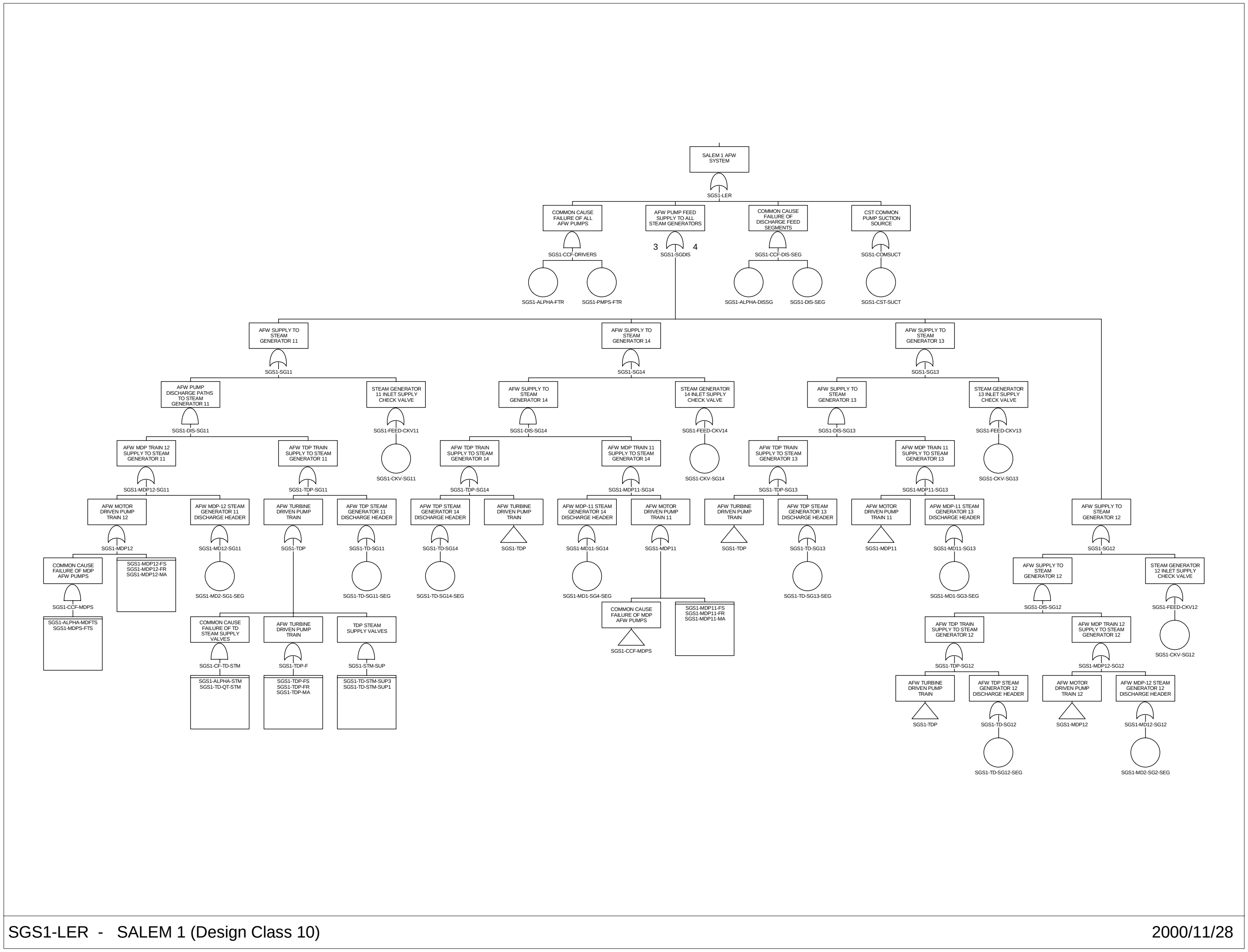


Figure 10. Design Class 10.

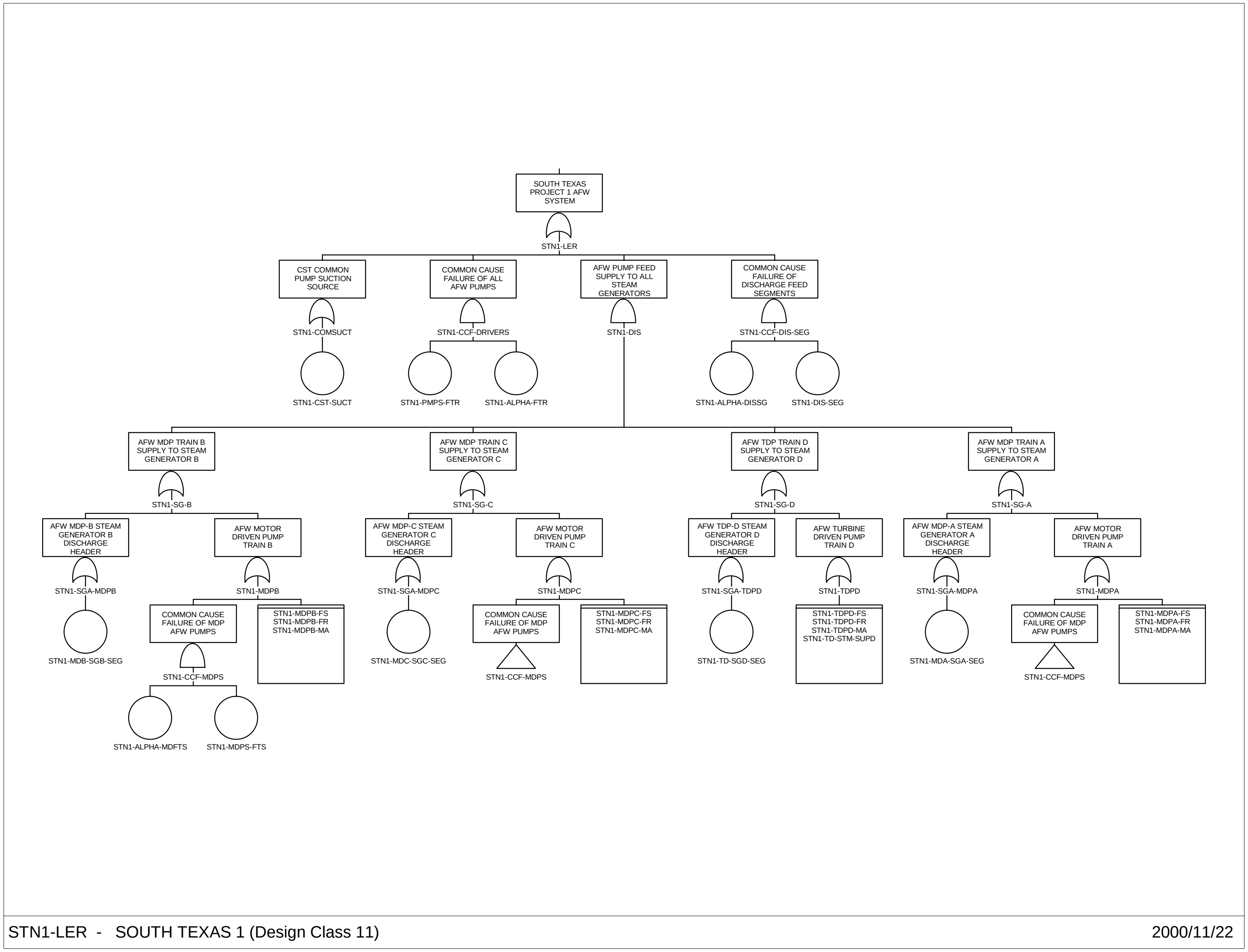


Figure 11. Design Class 11.